Optimization of Airport Operations

Event:
« Les Pros de la RO »
ROADEF

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Agenda

Introduction

Airport optimization and simulation
- Stand and gate allocation
- Runway sequencing
- Aircraft ground routing
- Simulator and integration with optimization

Recognized Benefits

Conclusions

I) Motivation

II) What we did

III) Results
Introduction

Amadeus

- Amadeus is a technology company dedicated to the global travel industry
- We are present in 195 countries
- Worldwide, we are 12000+ people
- Our solutions help improving the business performance of: travel agencies, corporations, airlines, airports, hotels, railways and more.

Today’s presentation = Airports
Introduction

Why optimizing airport ground operations?

Facts:

• **842 Mi** of passengers/year (Europe)

• **50% more flights** in 20 years

• Main airports are already **congested** in peak hours

• Airport **infrastructure** is very **expensive**, take time, and has ecological impacts

• Airports are responsible of **10%** of total flight **delays** (reference, weather = 9%)

• Cost of delays = 100 to **200 MiEuros/year** (only airport delays)

• Emission at the airport = **50 kg CO₂** / min of taxi time per flight (reference, small city car = 0.05 kg/min)
Airport ground resources optimization

Three optimization problems
Introduction

Timeline: Research on Airport Operations at Amadeus

- Dec 2011: Very first optimization models (CP/MIP)
- Jan 2012: First heuristic methods
- Apr 2012: Prototype
- 2012 - 2013: Development and Deeper Research
- Sep 2012: 2 papers published
- Apr 2015: Product 2 running at Airport
- Sep 2014: Product 1 running at Airport
- Dec 2015: Implementation on more airports
- 10+ contributors
- 10+ presentations at conferences
I) The stand allocation problem
The stand/gate allocation problem

Problem:
- Assigning aircraft operations to parking positions

Our Contributions:
- New formulation (e.g., European objectives)
- 10+ solution approaches tested
- Proof of NP-Completeness
- Improved exact and heuristic methods
- Comparison to the literature: 2-7% solution improvements

Published:
Ref: J. Guépet, R. Acuna-Agost, O. Briant, J.P. Gayon. Exact and Heuristic Approaches to the Airport Stand Allocation Problem European Journal of Operational Research 2015

Conferences:
- AGIFORS, IFORS, TRISTAN, INFORMS, ROADEF
Optimizers running everyday

*Picture: Stand/Gate allocation system running in an European Airport*

*The system runs in 4 screens.*

*Screenshot: Gantt chart*
II) The aircraft ground routing problem
The aircraft ground routing problem

Problem:
- Routing aircraft between runways and stands

Our Contributions:
- New exact and heuristic methods
- Integration of industry indicators: OTP and delay (literature models consider total completion and taxi time)
- Proof that classical indicators are inconsistent with sustainable scheduling (opposite to taxi time)
- Published: J. Guépet, O. Briant, J.P. Gayon, R. Acuna-Agost
  The aircraft ground routing problem: Analysis of industry punctuality indicators in a sustainable perspective
  European Journal of Operational Research 2015
- Conferences: AGIFORS, ROADEF
III) The runway sequencing problem
The runway sequencing problem

Problem:
• **Sequencing** aircraft at the runway

Our Contributions:
• **New** exact and heuristic methods
• **Integration** with the ground routing to optimize the whole departure process
• Propose a model fully integrating both problems and an improved **iterative approach**
• Conferences:
  • ROADEF, AGIFORS
Excellent results on the individual problems ...

- what really happens during the day of operations?
- what are the interactions between them?
- what happens if there are disruptions?
- do individual optimal solutions bring overall good operations?
and then we tried analytical solutions ... 

... mmm maybe better to try to put everything in a simulator ...
Simulator + Optimizers

Studying the interaction between different optimization problems
Simulator, 3D view

Some screenshots

Departing Sequencing

Pushback
Recognized Gains

Achievements

- Optimizers are part of two new products
- Software running every day (second) in important European Airports
- Several other airports worldwide have shown interest (still under negotiation): Asia, North America, and Europe

Published results (see Figure on the right):
- Runway waiting time reduced by 50%
- Improved flight slot adherence by 22%
- Delays recovery capability improved by 24%

Monetary gains estimation:
- See next slide

Press release, March 2015:

Munich Airport adopts Amadeus’ A-CDM solution improving flight departure planning & runway capacity

- Amadeus Airport Sequence Manager, part of the A-CDM offering, contributes to optimising airport resources, reducing airlines’ fuel costs, CO2 emissions, bringing benefits to the whole airport ecosystem

- Airport reduces runway waiting time by 50%, limiting fuel wastage as a result

- Munich’s inbound delays, compared to outbound flight delays improved by 24%

04/03/2015.

Madrid, Spain, 4th March, 2015: Amadeus, a leading technology provider for the global travel industry, today announces that it has contributed to optimising
Monetary Gains

Monetary value estimation for Stand/Gate Allocation System

Note: Simulations based on a “standard” airport, actual values cannot be disclosed

This represents an increase of

\[ \sim 1\% \] of yearly profits

Picture: Obfuscate screenshot of the value calculator

Developed and tuned in collaboration with airport experts and real data.
## Conclusions

### Problem
- Airports are a **bottleneck** of air transportation
- All major European airports are **congested**
- 50% more flights expected in 20 years
- 10% of total flight **delays** comes from airports
- 100 to 200 Mi Euros of airport delay **costs**
- 50 kg CO2 / minute of taxi time per flight

### What we did
- We addressed 3 optimization **problems** and their integration
- 15+ alternative optimization approaches were tested
- **Simulator** integrating several optimizer and visual features (3D)
- 10+ presentations at **conferences**
- 2 published **papers**
- 1 PhD **Thesis**
- 10+ **researchers** have contributed
- Optimizer are part of 2 new Amadeus **products** in the market

### Results
- European Airports using our tools **everyday** (many others are interested)
- Runway waiting time **reduced** by 50% (real)
- **Improved** flight slot adherence by 22% (real)
- Delays recovery **capability improved** by 24% (real)
- 1% potential **extra profits** for Airport operators (theoretical)
- 20% potential **reduction** of CO2 **emissions** of taxi time (theoretical)
Contributors

(alfabetic order)

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Olivier Ratier (Amadeus)
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Appendices
Publications

Research Work of Amadeus on this topic


- Rodrigo Acuna-Agost, Daniel Perez and Julien Guepet. *An Exact Solution Approach for the Airport Stand Allocation Problem*. TRISTAN VIII, San Pedro de Atacama, Chile (2013)


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- **Fast**: Fast Optimal / less development, Scales well / non linear objs
- **Suboptimal**: Optimal / less development, Good ratio: quality/speed
- **Impractical for large instances**: Best approach for large inst., Good Bounds
- **Commercial solver dependency**: Less memory, No Feasible Solutions
- **Commercial solver dependency / Slow convergence**: Slower than MIP
- **Suboptimal**: Good Bounds, Impractical for large instances
Implemented Solution Approaches

One of the best results

- MIP
- "Smart" Decomp. of the problem
- Improved Presolving
- Symmetry breaking procedure

Improvements:
- 100 times faster
- We can deal with huge instances CPU < 1 minute
- Optimal Solution => Gap = 0%

One of the best results